The Manned Spacecraft Center in Houston. The Practice of Matrix Management *

by

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Introduction

The historic moon landing truly represents a triumph of man's ingenuity. To say the achievement of the Apollo program's primary objective was a team accomplishment merely verbalizes the obvious. The program success was the result of a combination of many human and physical elements. Chief among these elements was managerial capability which acted as the catalyst to change the factors of this feat from potential to kinetic attainment. During the Apollo program, such talent manifested itself in many ways from problem identification to problem solution. This article serves to focus attention on the uniquely developed managerial practices and approaches at the Manned Spacecraft Center (MSC) in Houston. It also serves as an overview of the dynamics of a complex organization and of the unorthodox articulation of organizational energies and systems.

Manned Spacecraft Center in Houston

The Houston Center is one of eleven field installations of the National Aeronautics and Space Administration (NASA). The overall mission of MSC is to manage the development and testing of manned spacecraft and related equipment, select and train flight crews, and develop and apply space flight techniques and controls (Houston becomes the focal point for all flights as Mission Control takes over direction twelve seconds after lift-off). The interdependence of the three elements — spacecraft, crews, and mission — requires that they be managed through a synergistic systems approach.

The formal organization structure of MSC, which is depicted on the standard organization chart on page 2 (Figure 1), does not reflect the reality of MSC management.

A closer approximation to the reality of the management dynamics at the Center is suggested in Figure 2. This is more than a "space age" portrayal of a structural-functional system. Just as the components of our own solar system are held in juxtaposition by the forces of nature, so also does each "planet" at MSC owe its position to more than just interaction with the "sun" (Director) or its moon(s). Each planet (directorate) interacts with all components of the system to bring about a balance or stability which serves to maintain the system.

Management Philosophy

Several early decisions which constitute the basic philosophy of NASA have had a major impact on the organization and management at the Manned Spacecraft Center. One significant decision was that NASA would be an agency which performed technical management of a government-contractor-university team rather than be the designer and manufacturer of its own hardware in NASA facilities (during

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Apollo 11 there were approximately 4,400 civil service and 10,000 contractor personnel directly engaged in the mission in and around MSC-Houston). The research and development nature of the space program required a team effort between NASA and contractor personnel working together to plan the program, ascertain requirements, develop specifications, and design the hardware. It also meant an emphasis on procurement which led to significant experiments at MSC in the organization of procurement activities.

Procurement and every other MSC activity was also significantly affected by NASA's own adoption of the matrix management system under which each element of an organization is at an intersection of influences from other elements and itself influences several others. It is a system which tends to diminish the visibility of authority and to emphasize consensus as an operative mode. NASA also adopted the *program* approach, within the matrix structure and process.

MSC, because of its central role in the achievement of the goal of the first manned landing on the moon, is a test of the soundness of NASA's approach. As such, it is an excellent case study that not only demonstrates what happens to such administrative approaches in practice but also sheds light on the nature of the key elements in those approaches.

NASA/MSC Interface

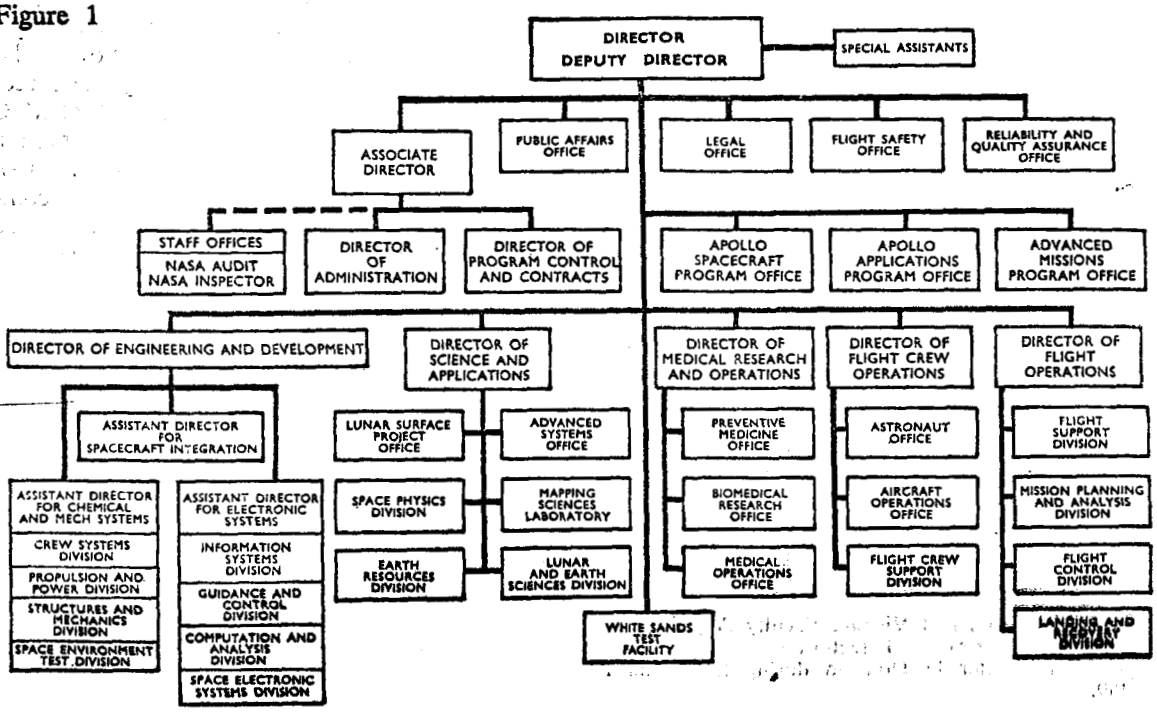
In the end, the Manned Spacecraft Center is what it is primarily because of the managerial skill of its own leadership and the flexibility of its own workers. But, overall NASA management philosophy provides the general framework within which MSC operates, and NASA's organization furnishes important levers through which MSC's organization remains vital.

For one thing, NASA Headquarters plays a key role as a catalytic moderator among the various Space Centers including MSC, but also including such important organizations as the Marshall Space Center at Huntsville, Alabama, and the Kennedy Space Center in Florida. It is NASA Headquarters which finally assigns specific space tasks to the several centers and insures the coordination of one center with another within a particular program.

Moreover, the matrix system of management at MSC parallels the matrix system of NASA. This very use by NASA of the matrix principle means that final orders from NASA Head-

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
Houston, Texas

Figure 1



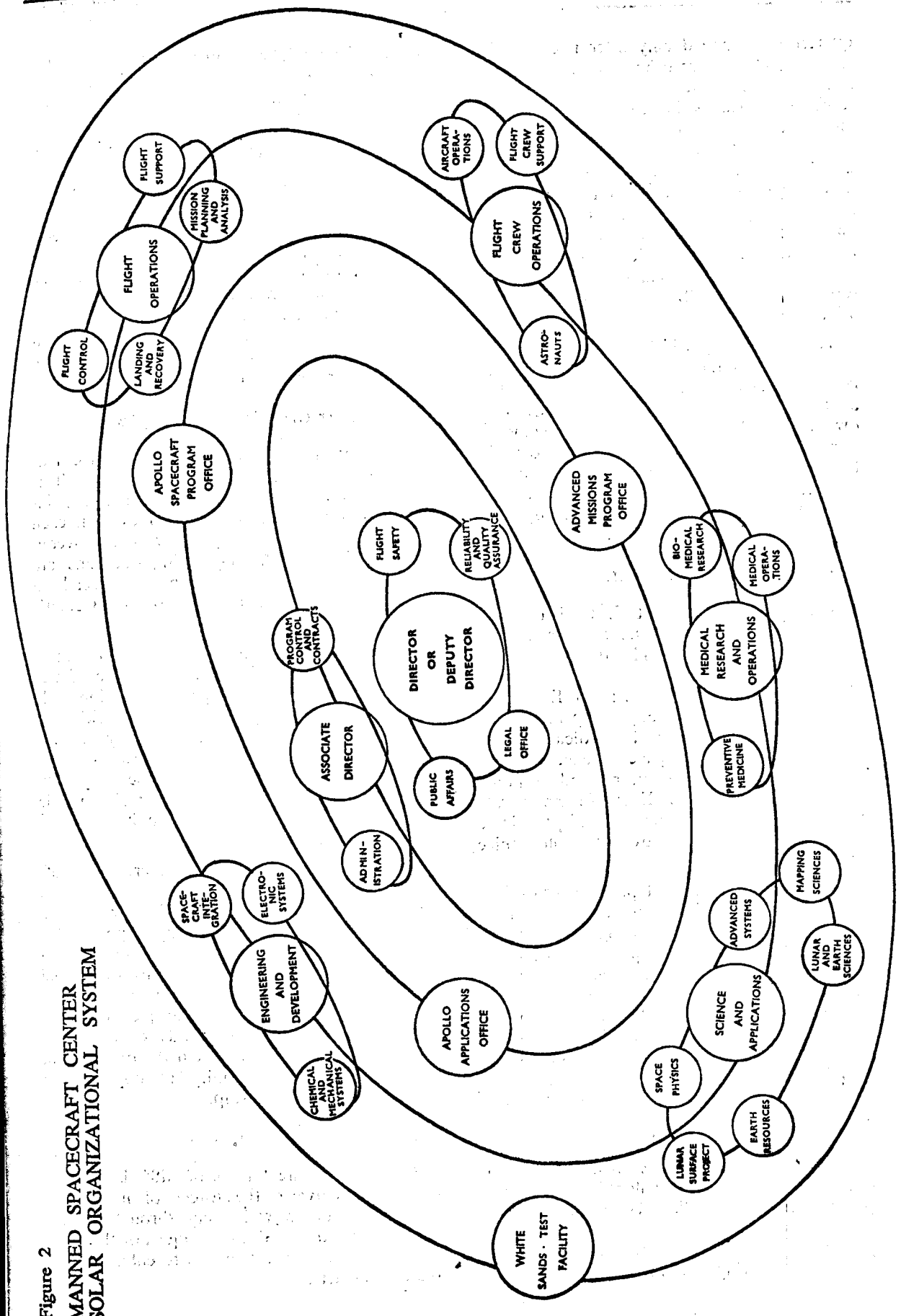


Figure 2
MANNED SPACECRAFT CENTER
SOLAR ORGANIZATIONAL SYSTEM

quarters are shaped only after relevant directorates and program offices at MSC and other centers are consulted. It also means that to some extent MSC's directorates are encouraged initially to considerable independence. NASA thus serves to introduce into the policy process long-term considerations of program strategy, including those based on the realities of national budgets and politics. Its program and mission documents also serve as ways of channelling the roles of particular units of MSC, and provides the guidelines for control by the top leadership of MSC over the Center's operations.

The method by which NASA defines roles and responsibilities both within MSC and between MSC and the other centers and the analogous subsidiary guidance by MSC of its own units, all assume that MSC is something more than an aggregation of spirited organizations led and staffed by competent, energetic people. It assumes that the fluidity of competition is given order by a leadership which helps men to work as a team.

MSC Organizational Formats

The Manned Spacecraft Center is organized both in terms of *functional management* and *program management.* The functional organization has a typical structure. It consists of Directorates responsible for: (1) Engineering and Development; (2) Flight Operations; (3) Flight Crew Operations; (4) Medical Research and Operations; (5) Space Science and Applications; (6) Program Control and Contracts; and (7) Administration. Each of these operates in a fairly autonomous manner and participates as necessary to achieve overall Center objectives.

Functional management provides centralized professional leadership and continuous monitoring, evaluation, and reporting to senior Center officials on Centerwide policies, procedures, and operational practices in a given functional area. Generally, a functional area is a specific professional or managerial discipline such as Medicine, Space Science, Flight Crew Operations, or Program Control and Contracts. In addition, these units often have important ties to the professional community at large from which they may bring resources to bear on specific problems.

On the other hand, *program* management is one established for, and tailored to, a specific program such as Apollo. It acts as a general management activity aimed at integrating the planning, controlling, supervision, engineering, and manufacturing activities involved in producing the end item. Any program organization is a temporary system. The achievement of its goal means the end of that particular organization. The Program Manager has no *formal* line authority over the functional units at MSC but he has determinative authority over the configuration of the elements of the mission.

In MSC's administrative operation every component of the organization is part of a complex universe. Functional Directors and Program Managers are partners in an alliance aimed at mission success. They are impelled by empirical pressures as well as specific management devices to cooperate on all phases of program development and execution.

MSC Matrix Organization Principles

The central concept governing decisionmaking at MSC is matrix management. This sees every unit of the organization as a point of intersection of competing forces with each part giving particular expression to the overall organization's goal. Operating decisions are the product of the give and take of specialized units struggling for a share of the Center's total resources.

However, a key part of matrix management as exemplified at MSC is the presence of elements with the power of precise decision, able to freeze the dialogue of decisionmaking at *ad hoc* points. In place of hierarchy and the pressure to conform to directives from the top, matrix management MSC style, tries to substitute operating unit drive for expression within a climate of mutual respect united around fundamentals.

At one and the same time, therefore, MSC projects both a strong tone of competition among program offices and directorates and a sense of unity and common purpose. On the one hand, more than is usually true in establishments that are governed by traditional concepts of hierarchical management, at MSC the game is always open, the pie is always being sliced, and the demands of time and reputation are inexorable. On the other hand, structured elements that unify are supplemented by the force of leadership.

Creative Tension

Each of the directorates of MSC is an area of tension between the forces of integration and fragmentation which cut through MSC's total organization. The techniques of the Center's management are designed to enhance both these tendencies.

Disintegration tendencies derive, for example, from the Medical Directorate's responsibility for looking to the health of the astronauts and for conducting medical experiments on the missions. Similarly, the Flight Crew Operations Directorate must look to the morale of half a hundred astronauts, all highly motivated men whose reward is space flight. And, the Flight Operations Directorate is responsible for supervising a mission where the safety of the crew is paramount, where engineering demands are heavy, where there is limited time even for dealing with the essentials to life and the maintenance of an accurate trajectory. The Engineering and Development Directorate is moved by the sense of being the avant-garde of the pioneers of space flight, meeting the problems of spacecraft design in an imaginative way, anticipating new modes of space and other extra-terrestrial travel on and above the surface of moons and planets, and staving off the enormous demands of other directorates for space. And the Science and Applications Directorate easily responds to the pressures of the scientific community that their interests be represented in the handling of experiments on missions.

Unifying Techniques

Into the world of autarkies at the Manned Spacecraft Center, top management has introduced a number of unifying techniques. One of the key sets of controlling devices in MSC's administration is allotted to the Associate Director. The responsibility for the overall planning and direction of the administrative and management activities necessary to support ongoing MSC programs is assigned to him. He is the principal advisor to the Director and Deputy Director of the Center regarding overall management of programs and operations. Two major organizational entities have been identified which encompass his sphere of authority: (1) Program Control and Contracts; and (2) Administrative and Technical Support Services. These units have the responsibility of providing contract management, procurement functions, and other technical and administrative support for the Center.

The Associate Director makes neither operational configuration nor strategic decisions. Rather, he translates policy into money, material, and personnel. This he does through the control he has over the total Manned Spacecraft Center budget, overall procurement functions in a strongly contract administration establishment, and overall personnel administration.

Another important unifying technique has been the assignment of Program Offices to a superior role in decisionmaking. The Apollo mission is meant ultimately to be held together organizationally by the Apollo Spacecraft Program Office (ASPO) whose chief officer is the Program Manager.

One of the primary tools of coordination used by ASPO has been the Apollo Spacecraft Configuration Control Board (CCB). This board is charged with the responsibility for the design of each particular mission in all aspects — from the form and construction of the command and service module to the design of extra-vehicular life support equipment, to the determination of the time parameters of each mission. The principal members of the CCB are the heads of MSC's technical directorates, though a few other key personnel are also members. The design of a mission is determined by the CCB within the limits placed on MSC by NASA Headquarters in the Apollo Program Development Plan (PDP), and is expressed in a set of mission planning documents ranging from the Apollo Mission Operations Plan to the Flight Plan itself. All aspects of the mission, from scientific experiments to abort procedures, are expressed in these controlling documents. Hardware design is approved by the CCB in detail. Basic design and procedure decisions follow presentation to the CCB at its weekly meetings by MSC personnel or representatives of contractor organizations. Once the basic design decisions have been made, they can only be changed by CCB action.

Anyone having attended a Configuration Control Board meeting cannot help but be impressed by the value of a meeting which brings the mature and imaginative thinking of senior officials to bear on the operating essentials of a complex mission. A key principle, however, is that while the CCB is designed as a way by which the views of all MSC offices and directorates can be inserted into operations as well as the specific proposals of contractors, the final decision is that of the Chairman of the CCB (the Manager of the Apollo Spacecraft Program Office). Specific Configuration Control Panels (CCP) are established to function in greater detail on hardware configuration matters. Hardware changes operate within a set of control procedures which provide for considerable latitude to contractors and to CCP's in making changes. This holds true so long as certain financial limits of the cost changes are not exceeded and so long as weight and schedule specifications are adhered to. Any such changes (cost, weight, schedule) must

be approved by MSC's Configuration Control Panels or the Configuration Control Board. Wherever there would be an impact from hardware changes on the work of other NASA Centers, approval of proposed changes is required from Headquarters.

Although the basic functions of mission planning are the responsibility of the Flight Operations and Flight Crew Operations Directorates, the complex interrelationships of all aspects of the mission suggest that top level control of the total process should rest with the Apollo Spacecraft Program Manager. In fact, however, the matrix system modifies this abstractly conceived rule into a more complex procedure. The Manager controls all changes which would influence mission requirements, hardware or software, mission rules, trajectories, schedules, propellant requirements, and mass properties. Controlling documents are periodically issued reflecting the current mission hardware configuration and planning status. Other configuration boards must adapt their decision to reflect consonance with the Apollo Spacecraft CCB approved documents. Difference of opinion is resolved during regular CCB meetings. This means that outside of a limited range of clearly perceptible minima with which the ASPO Manager can deal, there is a whole field of problems relative to mission operation where agreement can only be by an agreement among equals.

The usefulness of the CCB as an integrating, coordinating, determining, and directing device has led to CCB-type committees being set up at other points in the Manned Spacecraft Center in an effort to draw together relevant elements at the Center.

Sub-Systems Management

The Configuration Control Board is itself a specific expression and extension of the fundamental matrix technique of sub-system management. The chief feature of this device is the simultaneous operational responsibility of certain sub-units of functional directorates both to the leadership of their Directorate and to the Program Office. For example, the Lunar Surface Project Office of the Engineering and Development Directorate reports both to the head of that Directorate and to the Manager of the Apollo Spacecraft Program Office.

A variation of the sub-system technique is that of locating several engineer-staffed units in the Science Directorate in order to facilitate communications between the science community and the engineering elements at MSC.

Co-Location

An application of the sub-system principle is the technique of co-location. There are several instances where personnel from different directorates involved in a particular program project are housed together. In a number of cases, contractor personnel are officed together with civil service employees. This is so, for example, in the building that houses Mission Control at MSC, where Philco Corporation personnel are permanently housed alongside civil service specialists in mission control planning operations.

A somewhat unusual version of co-location was exemplified by the Apollo Spacecraft Program Manager holding CCB meetings at the work sites of the principal Apollo contractors. For instance, meetings were held with North American at Downey, California, for the command and service module. Similarly, meetings on the lunar module were held at Grumman's Bethpage, Long Island plant.

Work Package

To further insure the flow of communications among engineering and program specialists, MSC has developed the " work package " system. Although functional directorates have some directly allocated budget funds, the bulk of their operational revenues come from agreements with the program offices to provide specific technical support. It is the responsibility of the individual program offices or indeed any functional directorate, to persuade a directorate to work with it in the development of equipment or software and to arrive at an agreement much like the one that would be reached with a private contracting firm. In this way, the resources of such a directorate as Engineering and Development have been brought to bear on problems like the docking hardware and technique of the command and service module and the lunar excursion module.

A further significance of the work package system in the management process at MSC is that it provides for systematic monitoring by the Center Director of the work of directorates on program projects in terms of rate of expenditure of funds, adherence to schedule, and quality of performance.

Matrix Entrepreneurs

Matrix management at MSC is then a world of individual entrepreneurs, each of whom works to attract and retain outstanding talent. Each fights to insure that his group of men

is able to inject its own specific ideas into the development and execution of missions and programs within the framework of broad directives from NASA Headquarters. All this is subject to the coordination and direction of senior leadership at MSC and in the Program Offices.

Critics may say that MSC's matrix system, eschewing traditional hierarchical arrangements, can work and did work because of the vast sums the American public was willing to give the Apollo program. It is as likely that this system worked because its method of democratic involvement and decision by bargaining modified by provision for firm decisionmaking at certain times and places, all held together by experienced leadership, is particularly compatible with modern philosophies of management. Tied together with a clear goal and a clear system of contract administration, it has proved to be a stimulator of innovation in a system of fluid order.

The Procurement Function — An Application of the MSC Management Concept

Management at MSC has, since its inception in 1961, been oriented to progress through change. Illustrative of this concept is the fact that seventeen reorganizations have taken place during the eight years of the Center's existence. Throughout these changes, management has never hesitated to depart from traditional organization structure in order to improve functional performance.

The procurement function serves as an example of a shift to an unorthodox industrial organization arrangement, although it is not unknown in certain governmental operations. The present procurement arrangement was conceived in 1967 by MSC management as a means of dividing workload and solving specific problems. Before this time, all procurement activities were concentrated in a division of the Administration Directorate. The subsequent workload division resulted in major R & D programs being assigned to a newly created Program Control and Contracts Directorate. Support programs remained in the Procurement Division within the Administration Directorate.

It might be said that management discarded the idea that the organization chart had to be a text-book example and instead simply viewed the new structure in light of how best to accomplish the particular and unusual job with available personnel.

There were two reasons for adopting this divided organizational structure. First, to make it possible for some of the top procurement personnel at MSC to concentrate on work with the major programs only and to free these people from the work concerned with less expensive or less complicated procurements. It had been discovered that the small, less significant contracts had problems which, under the older system, caused top procurement management to expend so much time and effort that insufficient attention was being given to major contracts. This arrangement was, therefore, an effort to split away these less significant contracts and make it possible for top procurement personnel to concentrate on the more costly and complicated programs.

Second, the change was made in order to more closely align the other activities of resources management including budgeting, cost analysis, and scheduling with major R & D contracts. By integrating these functions into a single organization an attempt was made to establish Centerwide control of the administration of all programs. The Program Control and Contracts Office directly supports the Center's major R & D programs in the execution of these functional specialties, and will also serve as a focal point for the integrated analysis of the program status. Such analysis provides a better means of correlating the status of the major spacecraft programs with the operational effort required to support them, and provides a better means of analyzing the interrelationships between them.

Program Control and Contracts Directorate is in charge of contract negotiation and administration on *major* research and development programs assigned to the Center. The line relationship is to the Associate Director of the Center. This means that, as far as procurement is involved, the directorate is responsible for the establishment, execution, and control of policies relating to the activities of program offices.

There have been exceptions to this rule and there is the unanswered question of what is a major R & D program and what is not. To illustrate division of work, the Apollo command and service module is a major procurement program handled in the Program Control and Contracts Directorate. The procurement for this program includes the Apollo space capsule and supporting equipment. On the other hand, the Procurement Division in the Administration Directorate handles contracts that service the Manned Spacecraft Center such as equipment, supplies, principal scientific in-

vestigators, etc. These two examples are rather clear cut and provide little difficulty in being properly placed between the two procurement areas. However, the Administration Procurement Division also has responsibility for R & D *supporting* major programs. There apparently are no clear lines of distinction between which are support programs and which are not, and between which should be assigned to Administration Directorate and which should be assigned to the Program Control and Contracts Directorate.

Pros and Cons of Divided Procurement Function

The disadvantages are felt primarily *within* the two procurement groups and for the most part are related to personnel problems. There is the possibility that procurement personnel in the group handling smaller, less significant contracts will be dissatisfied because they feel that top management views their job as less important. It is a fact that division of procurement specialists between directorates has lessened the flexibility in handling personnel. There is very little movement of specialists from one directorate to another. In training, there is sometimes duplication of effort and in some instances the danger of training from differing viewpoints.

Both the NASA Headquarters office and contractors find themselves dealing with two different procurement offices at the Manned Spacecraft Center. Communications between the two procurement groups are more difficult and cumbersome than under the older single procurement effort. It is possible for a situation to develop where the buyer of a supporting device does not have sufficient information about the major hardware which makes it more difficult for him to maximize his buying effort.

The original goal of establishing the new Program Control and Contracts Directorate included that of support for procurement and budgeting that would not be completely dominated by a program office viewpoint. This was a difficult goal to attain because of the fact that the personnel working on procurement-related activities in the Program Office had no direct responsibility to the Director of Program Control and Contracts. A partial solution was attempted in the case of the Apollo program by appointing this Director the Manager for Contracts and Resources in the Apollo Spacecraft Program Office, thus making this group of personnel directly responsible to him as far as these procurement-related functions are concerned.

Although there are disadvantages to having two procurement groups, the division of work does appear to have merit. It makes it possible to concentrate on major programs with top flight personnel and colocates significant functions. While communications may suffer between the major contract procurement group and the support group, there is the trade-off of improvement in communications between budget and cost analysis within major R & D procurement. If accomplishments appear to outweigh disadvantages, it is quite likely that the unique arrangement will continue even though the Manned Spacecraft Center may well experience other changes in structure. At this point in time, it is too early fully to evaluate the effects of this change. It remains a controversial matter.

Epilogue

Apollo 11 has been referred to as the most complicated piece of hardware ever conceived by man. The mind boggles when one tries to envision the total configuration of this undertaking from the millions of hardware parts through to the actual mission flight which encompasses a worldwide communications network. The managerial dimensions of the task are staggering, yet beneath it all lies a common factor.

This article has attempted to shed light on the magnitude of this managerial accomplishment, noting some of the managerial innovations, and drawing attention to one segment of the total effort. The administrative-management segment is perhaps less glamorous, and is prone to be overshadowed during the elation of accomplishment but it is one that plays a vital role in that achievement.